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MAD RIVER BASIN CALIFORNIA. BUTLER VALLEY PROJECT. WATER SUPPLY AND WATER QUALITY CONTROL STUDY

Federal Water Pollution Control Administration
San Francisco, California

May 1967

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MAD RIVER BASIN
CALIFORNIA

BUTLER VALLEY PROJECT

WATER SUPPLY
AND
WATER QUALITY CONTROL
STUDY

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHWEST REGION
MAY, 1969

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ABSTRACT

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I. INTRODUCTION

REQUEST AND AUTHORITY

In a letter dated July 21, 1965 the District Engineer, U. S. Army Corps of Engineers, San Francisco District asked the U. S. Public Health Service to determine water supply and water quality requirements in the vicinity of a proposed multi-purpose reservoir to be constructed on the Mad River near Butler Valley in northwestern California. This request and the subsequent study described in this report were made in accordance with: 1) a memorandum of agreement between the Department of the Army and the Department of Health, Education, and Welfare, dated November 4, 1958, based upon the Water Supply Act of 1958 (Public Law 85-500, Title III as amended by PL 87-88); and 2) Section 3b of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.).

During the course of this study the water pollution control activities formerly conducted by the Public Health Service were transferred to the Federal Water Pollution Control Administration, U. S. Department of the Interior. Accordingly, this report has been completed by the latter organization.

The provisions of Executive Order 11288, July 2, 1966 relating to Federal water resource projects have also been considered in this report.

PURPOSE AND SCOPE

The purpose of the study was to 1) estimate the future need for and value of municipal and industrial water supplies; 2) determine the need for and value of reservoir storage for stream flow regulation for water quality control; and 3) evaluate impact of the project on water quality. The study area was limited to the Mad River Basin drainage area and the Eureka Plain. The time horizon selected for benefit evaluation and projection purposes is the year 2070.

This report summarizes the results of engineering and economic analysis of existing information relevant to the proposed project, existing water quality and water uses, population and industrial growth, and projected water supply and water quality control requirements.

ACKNOWLEDGMENTS

The following agencies have supplied valuable assistance and data:

Department of the Army, Corps of Engineers
San Francisco District, San Francisco, California

Department of the Interior, Bureau of Reclamation
Eureka Field Office, Eureka, California

Department of the Interior, Geological Survey
Menlo Park, California

Department of the Interior, Bureau of Sport Fisheries and Wildlife
Division of River Basin Studies
Sacramento, California

California North Coastal Water Quality Control Board
Santa Rosa, California

California State Department of Fish and Game
Sacramento, California

Eureka Chamber of Commerce
Eureka, California

Humboldt Bay Municipal Water District
Eureka, California

Georgia-Pacific Corporation
Eureka, California

II. SUMMARY OF FINDINGS AND CONCLUSIONS

FINDINGS

1. The Mad River Basin drains approximately 497 square miles of the California Coastal Range. Annual runoff near Arcata averages approximately one million acre-feet. The Eureka Plain, the primary water use area, consists of approximately 220 square miles and drains to Humboldt Bay and to the Pacific Ocean. The location of the study area is shown on Figure 1 (see page 39).

2. The present (1960) population of the study area (70,000) is concentrated almost exclusively in the Eureka Plain and near the mouth of the Mad River. The upper drainage area of the Mad River is very sparsely populated (approximately 2,000 persons).

3. The economy of the study area is heavily dependent upon forest industries, such as lumber and wood pulp.

4. The major source of municipal and industrial water is the Mad River. The Humboldt Bay Municipal Water District (HBMWD), which obtains its supply from this source, is the major supply agency. Small communities and the rural population obtain water from local ground and surface sources.

5. The total annual developed municipal and industrial water supply is approximately 87,000 acre-feet, of which 85,000 acre-feet is controlled by HBMWD. Future development in the study area will require additional water supplies.

6. There are no significant domestic or industrial waste discharges to the Mad River.

7. Soil erosion adds a large amount of sediment to the Mad River. The resulting turbidity is presently detrimental to domestic and industrial use of this source of water.

8. The annual safe-yield of ground water sources is estimated to be 45,000 acre-feet. This source is best suited to supply the needs of small rural communities, isolated farm homes and irrigated agriculture.

CONCLUSIONS

1. The population of the study area is projected to reach 478,000 by the year 2070. It is expected that the major portion of this growth will occur in the Eureka Plain.

2. The following table summarizes estimated future annual municipal and industrial water requirements that are in excess of the currently available supply of 87,000 acre-feet.

ADDITIONAL WATER SUPPLY REQUIREMENT
(1000 Acre-feet/year)

Year	1970	1980	1990	2000	2010	2030	2070
	0	67	71	80	90	118	157

3. The value of storage in the Butler Valley Project Reservoir needed to meet future municipal and industrial water supply requirements is estimated to be $18,000,000 (present worth, 1970) or approximately $680,000 annually. These benefits accrue to the water users in the Mad River Basin, the Eureka Plain, and nearby communities. This evaluation is based on the least cost alternative method.

4. When developed the annual runoff of the Mad River will be adequate to serve future municipal and industrial needs in the study area.

5. Based upon waste discharge practices followed by the Regional Water Quality Control Boards in similar coastal areas, it is probable that future municipal and industrial wastes from the periphery of Humboldt Bay and near the mouth of the Mad River will be intercepted and discharged by ocean outfalls to the Pacific Ocean.

6. Considering water releases required for fishery maintenance and projected treated waste loads from the Blue Lake area, there is no foreseeable need for storage of water for stream flow regulation for quality control in the Mad River.

7. Observations of nearby Ruth Reservoir indicate that seasonally high turbidity and stratification would be experienced in the proposed Butler Valley Reservoir. It would be possible to selectively withdraw water of the best available quality if multi-level outlets were constructed. It is therefore recommended that a multi-level outlet be considered in the design of Butler Valley Dam.

8. Recreational use of the reservoir and surrounding areas is projected to reach three and one-half million visitor days by 2010. Adequate sanitary facilities should be provided so as to prevent pollution of the reservoir and adjacent surface and ground waters.

III. PROJECT DESCRIPTION

The Corps of Engineers is studying the Mad River to determine the feasibility of providing storage for flood control, irrigation, municipal and industrial water supplies, water quality control, fishery, wildlife and other recreational uses.

Preliminary studies by the Corps indicated that the construction of a multiple purpose dam and reservoir would result in the best comprehensive plan of improvement. The Butler Valley site has been tentatively selected as the most likely for development. The proposed dam structure will be earth fill with a crest elevation about 350 feet above the stream bed and will have an uncontrolled spillway. The reservoir capacity will be about 460,000 acre-feet.

The drainage area of the entire Mad River Basin is about 497 square miles, of which about 352 square miles is above the Butler Valley Damsite. The mean annual runoff at the site is about 740,000 acre-feet.

The California Department of Water Resources (DWR) investigated the development of the Mad River Basin as part of the California Water Plan. The findings of this study were presented in Bulletin 136, North Coastal Area Investigation, published in 1965 [17]. The extensive hydrologic and water use data presented therein provided valuable reference material for this study.

IV. DESCRIPTION OF STUDY AREA

LOCATION AND BOUNDARIES

The study area, located in the north coastal area of California in Humboldt County, is shown in Figure 1. The area includes the entire watershed of the Mad River, which extends inland from the coast through approximately 80 river miles of rugged, timbered mountains of the North Coastal Range and the Eureka Plain which drains to Humboldt Bay. Eureka is the major population center of Humboldt County. Mad River is the principal source of water supply for Eureka and other smaller communities located on the Eureka Plain. Mad River tributaries include the North Fork of the Mad River, Maple Creek, Wilson Creek, Bug Creek, Boulder Creek, and Pilot Creek. Streams tributary to the ocean or to Humboldt Bay include Little River, Jacoby Creek, Ryan Creek, Elk River and Salmon Creek.

GEOLOGY

The Mad River Basin includes narrow scenic valleys and rugged mountains. Most of the area is covered by large stands of redwood and Douglas fir. Elevations vary from sea level to approximately 6,000 feet. The streams in the Coastal Range tend to flow parallel and in a northwesterly direction, reflecting the northwest trending faults that predominate the area. The rock that underlies the area can be classed as clastic sedimentary or volcanic and associated rocks. The principal rocks are part of the Franciscan formation and range in age from late Jurassic to early Upper Cretaceous.

The rolling terraces of the Eureka Plain are more suited to irrigation than the remainder of the area, hence the majority of irrigated agriculture is located there. The plain is underlain with rocks that are predominantly marine sandstone, mudstones, and conglomerates ranging in age from Late Cretaceous to early Pleistocene [2].

CLIMATE

The climate is characterized by moderate temperatures and frequent, dense fogs. The average annual temperature is 52.3 degrees Fahrenheit with an average daily range of only 11 degrees. Inland temperatures in the summer are higher than on the coast. Temperatures are influenced largely by elevation and local topography. The sun shines an average of 49 percent of daylight hours. The prevailing wind direction is north. The average annual rainfall at Eureka is 38 inches with the heaviest rainfall occurring on the western slopes of the Coastal Range, decreasing inland and toward the south. Precipitation is seasonal with very little occurring from June through September. Moderate

snow falls occur at elevations above 2,000 feet, but only above 4,000 feet does snow remain on the ground for any period of time. The growing season is approximately 315 days.

V. WATER RESOURCES

QUANTITY OF SURFACE WATER

The principal source of water in the study area is the Mad River. The average annual discharge of the Mad River during thirteen years of observation was 1,140,000 acre-feet at the U. S. Geological Survey gauge near Arcata and 740,000 acre-feet at the Butler Valley Damsite [3].

At the present time the Humboldt Bay Municipal Water District (HBMWD) has the capacity to divert about 75 million gallons per day, or approximately 85,000 acre-feet per year, from Mad River at Essex. The District owns and operates Ruth Reservoir which is located on the Mad River about 79 miles from the river's mouth. Storage water released from Ruth Reservoir (capacity 52,000 acre-feet) flows 75 river miles to Essex where it is diverted from the river into the distribution system of the HBMWD. The diversion consists of Ranney collectors which intercept the water percolating through the river bed. From Essex, water is pumped to the Samoa Peninsula and to the metropolitan areas of Eureka and Acrata.

Elk River was an early source of supply for Eureka, but with encroachment of the watershed by the expanding city, it was abandoned as a source of municipal supply. Other coastal streams include Salmon Creek, Ryan Creek, and Jacoby Creek. The combined annual runoff of these streams is estimated to be approximately 600,000 acre-feet [4]. The total firm yield to be obtained from development of these streams is estimated to be less than 50,000 acre-feet per year.

Little River which discharges into the Pacific Ocean near Crannell is a potential source of supply. Consideration has been given to development of this river as a source of supply for the communities in the Little River and Blue Lake areas. The average annual runoff of Little River at Crannell, for the ten years of record, is 103,000 acre-feet. The yield from development of this source is estimated at 50,000 acre-feet per year. Local plans have been proposed for the development of this supply but action has not been taken at this time.

Under the proposed State of California Water Plan, Van Duzen River water will be transported through Ruth Reservoir and the proposed Anderson Ford Reservoir into the Sacramento River. Van Duzen River water will be mingled with runoff from the Sacramento River Basin in the Sacramento - San Joaquin Delta for export to Central and Southern California. Although Van Duzen River water will only be transferred through the Mad River Basin, it should be recognized

as a possible water supply source for the study area. Plans for the development of the entire Eel River Basin including the Van Duzen River are under study by an inter-agency group composed of the California Department of Water Resources, U. S. Bureau of Reclamation, U. S. Corps of Engineers and the U. S. Soil Conservation Service.

QUALITY OF SURFACE WATER

In 1962, the State of California maintained 32 stations on 19 streams in the North Coastal Region of California [5]. A typical analysis of surface water in the study area is shown in Table 1.

Water released from Ruth Reservoir flows across the Franciscan formation which consists of sandstone, shale, conglomerate, greenstone, and minor amounts of limestone and schist. This formation is hard and relatively insoluble and resulting mineral pickup in this area is small. The result is a calcium bicarbonate water with a low concentration of total dissolved solids. From Boulder Creek to Blue Lake, the Mad River flows across patches of softer sedimentary deposits of marine origin. The resulting water is still calcium bicarbonate but has an increased concentration of magnesium and total dissolved solids. From Blue Lake to Arcata the flow is across trace gravels of the Hookton and Rohnerville formations which contain iron oxides. However this distance is only three miles and the highest concentration of iron is approximately 0.10 mg/l [7]. Thus the flow of the Mad River from Ruth Reservoir to Arcata increases in mineral content but not enough to make the water unsuitable for most beneficial uses.

The flow of the Mad River is relatively unpolluted by domestic wastes because of the very small population and the limited human activity along the river. Water supplies are generally suitable for domestic use with a minimum of treatment. Eureka obtains its domestic supply from the Mad River with treatment by chlorination and filtration to remove suspended solids, and Arcata limits its treatment to chlorination. Small water users such as Blue Lake, Fields Landing, and Crannell obtain domestic supplies of satisfactory quality from springs and wells, with disinfection being the only treatment.

According to the U. S. Geological Survey Hydrologic Investigation Atlas, HA-235 [8], the mean annual surface water temperature of the Mad River is about 55 - 59°F with about one to ten days per year of temperatures exceeding 80°F.

Turbidity resulting from suspended solids appears to be the most serious water quality problem. Large variations in natural streamflow, which occur as a result of the seasonal variation in precipitation, flush

TABLE 1

TYPICAL SURFACE AND GROUND WATER QUALITY
MAD RIVER STUDY AREA

Constituents [a]	Surface Water: Mad River [b] near Arcata	Ground Water: Eureka Plain [c]
Date of Sampling	9-5-62	8-29-63
Discharge (cfs)	35	--
Temperature (^{o}F)	62	55
Specific Conductance (Micromhos at 25°C)	251	168
Dissolved Oxygen	9.3	--
pH	7.3	7.6
Calcium	37	5.9
Magnesium	6.0	9.1
Sodium	6.1	11
Potassium	0.9	1.5
Carbonate (CO_3)	2	0.0
Bicarbonate (HCO_3)	134	65
Sulfate	14	3.1
Chloride	5.1	14
Nitrate	0.2	1.2
Fluoride	0.0	--
Boron	0.0	0.0
Silica (SiO_2)	10	--
Total Dissolved Solids	147	93
Hardness (as $CaCO_3$)	117	52
Turbidity (JCU)	2	--

a/ All constituents in mg/l, unless noted.

b/ California State Department of Water Resources [5].

c/ California State Department of Water Resources [6].

sediments from the watershed into the river. During periods of high runoff, the waters of the Mad River are highly turbid due to the large sediment load. During the 1964 water year, the U. S. Geological Survey recorded a total sediment load of 12.3 million tons at their Arcata station [9]. The California Department of Water Resources, U. S. Geological Survey, and the U. S. Soil Conservation Service are currently investigating the turbidity and sedimentation problems in the Mad River Basin.

A water quality study in Ruth Reservoir has been made by the California Department of Water Resources. Their study indicates that thermal stratification occurs in the reservoir during the summer months. The dissolved oxygen at the surface varied from 10.8 mg/l during the winter months to 7.7 mg/l during the summer months. The dissolved oxygen concentration in the hypolimnion from August to October was below 1.0 mg/l. The water temperature was as high as 70°F at the surface during the summer months. The temperature near the bottom of the reservoir remained as low as 50°F during the summer.

The environmental conditions at Butler Valley are similar to those at Ruth Reservoir, indicating that water quality conditions in Butler Valley will probably be similar to those at Ruth Reservoir.

QUANTITY OF GROUND WATER

Ground water in the coastal area is derived from precipitation, which penetrates the marine terraces, and from surface runoff which penetrates aquifers immediately adjacent to the stream channels. The ground water in the coastal area is an important water supply source for irrigation and domestic supplies for small communities, farms and rural homes. The small communities of Blue Lake and Fields Landing are partially supplied from shallow wells. The estimated annual safe-yield of ground water in this ground water basin is about 45,000 acre-feet from a storage capacity of 130,000 acre-feet. Present well pumpage for irrigation and domestic use is about 15,000 acre-feet per year.

In the Upper Mad River Valley ground water is confined to the very narrow terraces of the valley, which are recharged primarily from local runoff during the wet season and from the river. During the summer months recharge from the Mad River is not dependable. Estimates of safe-yield are not available but are assumed to be insignificant.

The ground water of the entire study area is best suited for satisfying requirements for irrigation and domestic supplies of farms and isolated crossroad communities.

QUALITY OF GROUND WATER

The State of California has a ground water quality monitoring program in the Mad River Valley and the Eureka Plain. The monitoring program was established in 1957 in the Mad River Valley and in 1958 in the Eureka Plain [10]. The purpose of the program in both these areas is to detect sea water intrusion and to observe the general quality of ground water in the area. Table 1 shows a typical water quality analysis of the local ground water.

Ground waters in the Mad River Valley are generally bicarbonate in type with calcium or magnesium the predominant cations. The ground water is moderate to very hard but is considered suitable for most beneficial uses. There is evidence of sea water intrusion in the coastal part of the Valley. At Blue Lake, where complaints have been made of the high iron content of the local well water, concentrations as high as 21 mg/l have been reported.

The ground water in the Eureka Plain is of suitable quality for most beneficial uses - moderately hard, bicarbonate type with magnesium the predominant cation. The salinity content of ground water from depths of 20-100 feet within the tidal influence of Humboldt Bay prohibits use of this water [11]. Water in the dune sand near the shore is of sodium chloride composition.

V. ECONOMY

THE PRESENT

Forest

Timber resources constitute the primary base of economic activity in the study area. The cutting of lumber began in 1851 and initiated the growth of the forest industry which presently provides over 70 percent of the employment in Humbodt County. There are presently 85 lumber mills and forest products plants in operation. Lumber, plywood, shingles, veneer, and pulp are produced and shipped from the area [12].

The Georgia-Pacific Corporation placed a 500-ton per day pulp plant into operation in August 1965. The value of the plant is estimated at 50 million dollars. Construction has just been completed (1966) by Crown-Simpson Pulp Company of another 50 million dollar plant that also has a 500-ton per day capacity. Both plants are using a new process that utilizes redwood and douglas fir waste chips that were previously burned. Both plants employ the Kraft process for production of pulp.

Humboldt County is the prime producer of forest products in the State of California. The industry produces an estimated annual value of 170 million dollars of forest products.

Tourist Industry

The second largest industry in the area is tourism. The main tourist attractions are state and national forests, state parks, fish and game, and the scenic sea coast. The forests and sport fishing attract visitors from the population centers to the south. The total annual value of the tourist and convention industry in 1966 was estimated by the Greater Eureka Chamber of Commerce to be about 14 million dollars.

The establishment of a multi-purpose reservoir at Butler Valley will enhance the recreational potential of the area. Presently there are no large freshwater recreation sites within convenient distance of the population centered around Humboldt Bay. Ruth Reservoir is not readily accessible because of the inadequate mountain roads and distance.

Agriculture

Agriculture is one of Humboldt County's major industries, with the main activity located on the Eureka Plain. The agriculture of Humboldt County

has an annual value of approximately 13 million dollars. The rich, natural pasture land of the Eureka Plain is well adapted to the raising of dairy cattle. The annual value of dairy products in the area is 6.5 million dollars or about one-half the total agriculture income of the County.

The native grass along the coast and behind the timber belt provides excellent grazing land for Hereford beef cattle. The annual value of beef produced is roughly 1.5 million dollars. The production of sheep provides an additional one million dollars to the economy.

Field crops such as potatoes, carrots, lettuce, tomatoes, and corn are grown in the Eureka Plain and have an annual economic value of 2.7 million dollars for Humboldt County.

The annual value of Humboldt County agriculture since 1957 is shown in Table 2.

TABLE 2

VALUE OF AGRICULTURAL PRODUCTS
HUMBOLDT COUNTY a/

1957	$11,810,093.00
1958	10,839,870.00
1959	10,473,979.00
1960	12,824,896.00
1961	12,802,741.00
1962	12,747,115.00
1963	12,986,866.00
1964	13,196,420.00

a/ Greater Eureka Chamber of Commerce [12].

Fishing

Humboldt Bay is an important base for commercial fishing on the west coast. There are presently 450 registered boats that use the port throughout the year and another 400 that operate out of Eureka on a part-time basis. The Eureka area is the leading producer of fresh fish and shellfish in the state. Employment in the fishing industry varies from a high of 800 to a low of 200 people, for an average annual employment of 400 persons. The commercial fish catch has increased from five million pounds in 1943 to 25 million pounds in 1964. The total value of commercial fishing to the economy in 1964 was 12.5 million dollars.

The California State Department of Fish and Game estimated the total value of sport fishing for the entire north coast area at 6.5 million dollars. Of this total approximately three million dollars is spent in Humboldt County. About 1.8 million dollars is spent by visitors to Humboldt County and the remaining 1.2 million dollars by residents of Humboldt County.

Table 3 summarizes the value of the basic industries of the study area in 1965.

TABLE 3

ECONOMIC VALUE OF BASIC INDUSTRIES
HUMBOLDT COUNTY CALIFORNIA [a]
1965

Forest Product	$170,000,000	79.92%
Tourist and Convention	14,000,000	6.58%
Agriculture	13,196,420	6.21%
Commercial Fishery	12,500,000	5.88%
Sport Fishing	3,000,000	1.41%
TOTAL	$212,696,420	100%

a/ Greater Eureka Chamber of Commerce [12].

THE FUTURE

Population and Employment

Population and employment projections for the study area were supplied by the Corps of Engineers and are shown in Tables 4 and 5. The projections show the population of approximately 70,000 in 1960 expanding to 478,000 by the year 2070. The employment figures indicate that much of this population increase will be supported by the expanding industrial activities while employment in agriculture will decline.

Industry

The production of pulp by Georgia-Pacific Corporation and Crown-Simpson Pulp Company has provided a stimulus to the economy of the area. Local people and representatives of the pulp mills believe that this will provide a springboard to the production of finished paper and other forest products. It is projected that an additional pulp mill will be established in the very near future or that existing plants will be expanded. The new pulp mills and the resources of the area open the possibility of importing wood chips to the area to supplement local raw material for the production of pulp and paper.

There are low-grade iron, manganese, and chromite deposits in the area that could possibly contribute to future industrial development. These low-grade deposits have been worked in the past when government supported prices made mining feasible. Future governmental price controls, increased prices, or technological advances could make mining of these minerals feasible.

TABLE 4

POPULATION PROJECTIONS
MAD RIVER BASIN [a]

	1900	1970	1980	1990	2000	2010	2020	2030	2050	2070
Little River	3,814	4,500	5,300	6,200	7,200	8,300	9,500	10,500	12,200	13,500
Blue Lake	4,452	5,500	5,800	6,440	7,600	9,200	11,000	13,200	17,000	20,400
North Fork	2,398	2,600	2,700	3,000	3,300	3,700	4,100	4,600	5,400	6,300
Eureka Plain	57,200	77,470	100,000	127,000	163,000	205,000	254,000	310,000	394,000	430,000
Butler Valley	2,356	2,600	2,900	3,200	3,500	3,900	4,400	5,100	6,400	7,700
Ruth	289	300	350	400	440	460	500	520	560	600
Basin Total	70,509	92,970	117,050	146,240	185,040	230,560	283,500	343,920	435,560	478,500
Basin Total (Rounded)		93,000	117,000	146,000	185,000	231,000	284,000	344,000	436,000	478,000

[a] Source: Corps of Engineers, 1966.

TABLE 5

EMPLOYMENT PROJECTIONS
MAD RIVER BASIN [a/]

	1960	1970	1980	2000	2020	2050	2070
Agriculture	627	460	225	185	175	230	230
Industry	11,074	12,610	14,320	19,795	28,430	41,055	43,715
Other	15,199	20,430	25,855	39,020	60,495	92,215	99,655
Total Employment	26,900	33,500	40,400	59,000	89,100	133,500	143,600

a/ Source: Corps of Engineers, 1966.

VII. WATER REQUIREMENTS
MUNICIPAL - INDUSTRIAL

PRESENT WATER USE

Since 1962 the principal source of municipal and industrial water supply has been the Humboldt Bay Municipal Water District (HBMWD). In 1956 the District entered into contracts to supply the cities of Eureka and Arcata as well as the Georgia-Pacific Corporation and the Simpson Redwood Company, which are located on the Samoa Peninsula. These contracts are still in effect, although the original contract with Simpson Redwood Company has been assigned to the newly incorporated Crown-Simpson Pulp Company.

The original contracts with Georgia-Pacific Corporation and Simpson Redwood Company provided for the minimum purchase of 12.5 million gallons per day and a maximum of 19 million gallons per day for each plant. A new contract was negotiated and the district expanded its facilities to meet the increased demand. The present contract requires the HBMWD to deliver 30 million gallons per day to each pulp mill. This is an increase of 11 million gallons per day for each plant, with nine million gallons per day on a firm demand and two million gallons per day on an interruptable basis.

The present capacity of the HBMWD is approximately 75 million gallons per day. After the pulp mill requirement of 60 million gallons per day is met, 15 million gallons per day is available for municipal water supply. The average municipal use at the present time is approximately eight million gallons per day. The additional seven million gallons per day is considered to be obligated to the cities of Eureka and Aracata for their future needs.

Approximately 15,000 of the present population of 70,000 obtain their water supplies from sources other than the HBMWD. Blue Lake, McKinleyville, Fields Landing and Crannell obtain their supplies from surface waters or individual wells, and the scattered agricultural population use individual wells to supply their irrigation and domestic water supply needs. About 2,000 acre-feet per year is used in these communities and rural areas for domestic needs.

FUTURE WATER USE

The future municipal and industrial water requirements are largely dependent upon the production of pulp and other forest products. The production of pulp requires so much water (60,000 gal/ton) that future water requirements for other demands are relatively small by comparison. The present favorable

world market for pulp and the availability of resources indicate that a third pulp mill will probably be established as soon as an adequate water supply is available. The resources in the area have been estimated to be sufficient to support a pulp industry of approximately 2,000 tons/day [13]. With sufficient water resources and expansion of present capacity, it is possible that wood chips could be imported to expand production well beyond the 2,000 ton/day capacity that can be supported by local supplies. The water requirements for the production of pulp and paper has been reduced during the past, and technological advances in the future could greatly affect the amount of water utilized in pulp production. Mussey [14] reported that "the maximum amount of water used in producing a particular kind of pulp is 10 times the minimum." The quantity of water used in the production of pulp, especially bleached pulp, is, in part, a question of economics involving the quantities of bleach and water used. It should be kept in mind that all these factors could affect the future water requirements of the pulp industry, by far the largest water user.

Projected population and employment for the study area were supplied by the Corps of Engineers (Tables 4 and 5). These projections were used as a basis for estimating future water requirements to the year 2070. The procedure used in making the projection is outlined in Appendix A. The projected total water requirements increase from 81,000 acre-feet per year (72 mgd) in 1970 to 244,000 acre feet (217 mgd) in the year 2070. The heavy industry or pulp industry is projected to use 120 mgd by 1980 in producing 2,000 tons/day of pulp. The per capita domestic use increases from about 100 gallons per day in 1965 to 190 gallons per day in 2070. The projected water requirements are shown in Table 6.

The additional annual yield required to meet projected needs is obtained by subtracting the 85,000 acre-feet supplied by HBMWD and 2,000 acre feet supplied by individual sources other than HBMWD from the total requirements shown in Table 6. For the purpose of this report, it was assumed that the annual yield to supply the requirement of the Little River Area would be obtained from the Mad River. Thus the total annual additional yield necessary to meet requirements was found to be 157,000 acre-feet by the year 2070.

TABLE 6

WATER SUPPLY REQUIREMENTS [a]/
(1000 gallons per day)

	1965	1970	1980	2000	2020	2050	2070
Heavy Industry	25,000	60,000	120,000	120,000	120,000	120,000	120,000
Light Industry	1,107	1,261	1,432	1,980	2,843	4,106	4,372
Domestic	7,051	10,227	14,046	25,906	45,360	78,401	90,915
Service	304	409	517	780	1,210	1,844	1,993
Tourist and Recreation	33	55	87	163	190	190	190
Total (1000 gpd)	33,495	71,951	136,082	148,828	169,603	204,541	217,470
(AF/Yr)	37,500	81,000	154,000	167,000	190,000	229,000	244,000

a/ See Appendix A for Calculations.

VIII. WATER QUALITY CONTROL

WASTE LOADS

The city of Eureka sewer system services approximately 28,000 people. Treatment facilities consist of three primary treatment plants that discharge into Humboldt Bay. Eureka has a combined sewer system and the 1962 Inventory of Municipal Waste Facilities by the Public Health Service [15] states that the Eureka system "has no pollution abatement needs." The city of Arcata serves 7,800 persons by a treatment plant that discharges oxidation pond effluent into the north end of Humboldt Bay. The Arcata effluent has been reported to be contaminating the oyster beds that are located in Humboldt Bay. The city of Blue Lake serves 1,235 people by an Imhoff tank and oxidation ponds. The ponds are designed for percolation but surface overflows into the Mad River have been reported. McKinnleyville, Crannell, Korbel, and the rural population are presently treating domestic waste with septic tanks and percolation beds.

The Georgia-Pacific Company located on the Samoa Pennsula dispose of its untreated industrial wastes by means of a 3,000-foot outfall to the Pacific Ocean. The Crown-Simpson Corporation plans to utilize a similar system to dispose of its untreated wastes.

At the present time man-made wastes appear to have little influence on the water quality of the streams in the Mad River Basin. However, the outfalls into Humboldt Bay (Eureka, Arcata and Fields Landing) are of some concern. The pond effluents from Arcata and Fields Landing have been under study by local and State public health agencies. The city of Arcata has completed instillation and placed into operation facilities for chlorination of its sewage lagoon effluent.

WATER QUALITY CRITERIA

Water quality objectives have been established in the study area by the North Coastal Regional Water Quality Control Board (WQCB) of the State of California. The effluent from the Imhoff tank at Blue Lake is contained in oxidation ponds for percolation near the Mad River. It is recognized that overflows will occur during the wet season and this has been reported. Therefore, WQCB has established a requirement for Blue Lake that any discharge into the Mad River must be "adequately oxidized and disinfected." The U. S. Bureau of Sport Fisheries and Wildlife has proposed establishment

of a fish hatchery near Sweasey Dam. Maintenance of the fishery in the downstream area is an objective that should be recognized in establishing new water quality criteria in the Mad River. It is believed that a dissolved oxygen minimum of 6.0 mg/l will be required for the fishery, although this is not a quality requirement on the Mad River at the present.

The water quality goals of Humboldt Bay have been established by the WQCB under Resolution No. 61, adopted in April 1965. Humboldt Bay is surrounded by a large population and has recognized beneficial uses. Consequently the quality objectives are of a high standard. Eureka discharges primary and secondary effluent from three separate plants located on Humboldt Bay. Arcata and Fields Landing discharge pond effluent into the Bay.

The industrial waste ocean outfalls of the Georgia-Pacific Corporation and the Crown-Simpson Pulp Company must also comply with the water quality objectives established by the WQCB. The goals are not as restrictive as required within Humboldt Bay and are met by discharge of untreated industrial wastes. The wastes and the ecology of the receiving waters of the Pacific Ocean are monitored by the WQCB to insure compliance with the criteria established.

FLOW REGULATION

Within the area downstream from Butler Valley Dam, the only significant waste loads are from the Blue Lake and the North Fork areas. The area immediately downstream from the dam to the confluence of the North Fork of the Mad River will not be developed significantly since the area is rather precipitous and the valley is narrow, affording only a small bench land area for development.

Precedents established by the Regional Water Quality Control Board in similar conditions on other coastal streams indicate that future requirements will preclude discharge of effluent into the Mad River from areas near its mouth. A collection system with an ocean outfall would be the most feasible solution for disposal of waste from areas close to the Pacific Ocean. Similarly, present discharges into Humboldt Bay will likely be eliminated in favor of ocean outfalls. These requirements will become more obvious as population around Humboldt Bay increases. An ocean outfall system would preserve the many beneficial uses of Humboldt Bay and the area around the mouth of the Mad River.

The Bureau of Sport Fisheries and Wildlife is cooperating with the California Department of Fish and Game to determine minimum releases for the fishery in the Mad River below Butler Dam. Minimum flows will be

necessary for the proposed fish hatchery near Blue Lake and for fish flows in the Mad River to the Pacific Ocean. The Bureau of Sport Fisheries and Wildlife have estimated that the following flows will be required:

Period	Downstream from Butler Valley Dam (cfs)	Into Pacific Ocean (cfs) 1/
Oct. 16 - April 30	300	300
May 1 - June 30	200	150
July 1 - Oct. 15	100	45

By stipulation and agreement with the Department of Fish and Game, the HBMWD agreed to bypass a minimum of five cubic feet per second into the natural streambed of the Mad River immediately below Ruth Reservoir. In addition the HBMWD agreed tomaintain flows in the Mad River immediately below Essex at the natural level or a minimum of the following flows, whichever is less [16]:

October 1 - October 15	30 cfs
October 16 - October 31	50 cfs
November 1 - June 30	75 cfs
July 1 - July 31	50 cfs
August 1 - August 31	40 cfs
September 1 - September 30	30 cfs

The ten-year flow duration curve for the Mad River near Arcata, California indicates that the natural flow of the stream would be equal to or greater than 30 cubic feet per second 92.1 per cent of the time [17]. Therefore, fish flows below Essex by present agreement can be expected to equal or exceed 30 cubic feet per second 92.1 per cent of the time.

A dissolved oxygen concentration of 6.0 mg/l for maintenance of a cold water fishery was determined to be adequate for present and future beneficial uses of the Mad River below the proposed Butler Valley Dam. The flow requirements necessary to maintain this standard for future projected waste loads were computed. A treatment efficiency of 85 per cent BOD removal was used throughout the study period. An increasing treatment efficiency was not utilized because natural runoff from forest areas will not be subject to treatment. The results, shown in Table 7, indicate that the maximum flow required to maintain a dissolved oxygen level of 6.0 mg/l will be 20.4 cubic feet per second in the year 2070.

The fish releases presently required are larger than the requirements for water quality flow regulation. It is therefore concluded, in view of the best information available, that flow regulation for water quality control from Butler Valley Reservoir into the Mad River is not required at this time.

TABLE 7

FLOW REGULATION REQUIREMENTS
IN THE MAD RIVER

Year	Required Flow, cfs
1970	5.8
2000	8.0
2030	13.7
2050	17.6
2070	20.4

IX. BENEFITS

EVALUATION METHOD

The single purpose, least cost alternative was used to determine the value of the municipal and industrial water supplies. The least cost alternative method assigns a value to a water supply that is equal to the cost of providing that supply. Use of this method is based upon the assumption that the benefits of the project warrant the measures required to achieve them. With this assumption the method gives an estimation of the minimum dollar value of the benefits.

ALTERNATIVES SUPPLIES

Several alternative methods of supplying future water requirements are available. Eel River and Van Duzen River water can be diverted into the study area. Small local streams such as Elk River, Little River, Jacoby Creek, or Ryan Creek could be developed to provide an interim supply. The Mad River can be developed to supply the total additional requirements.

Eel River and Van Duzen River water was considered by diversions, either in the upper basin through Ruth Reservoir or at the Eel River Delta. The cost of importing water to the study area from other basins is estimated to exceed the cost of developing alternatives within the Mad River Basin Futhermore, present plans of the State of California provide for the exportation of surplus water from the Eel River Basin to Central and Southern California.

Development of the small streams discharging into the ocean and Humboldt Bay was also considered, but the combined yield of these sources would not meet the total water requirements of the study area. It is believed that these small coastal streams are suitable only to meet local needs.

The initial construction of Ruth Reservoir provided for possible future expansion of the site. Expansion of Ruth Reservoir is limited by safety considerations to a storage capacity of approximately 80,000 acre-feet which will provide an annual yield of approximately 112,000 acre-feet at Essex, an additional yield of 27,000 acre-feet over the present supply of 85,000 acre-feet available from Ruth [18]. As shown in Table 6, the total water supply requirements of the study area are expected to increase to 154,000 acre-feet per year by 1980. Thus, even with an enlarged Ruth Reservoir, it would be necessary to supplement the supply with an additional source. The exact date is dependent upon development of the pulp industry. For the purpose of determining the single purpose, least

cost alternative it was assumed that the Anderson Ford Damsite on the Mad River below Ruth Reservoir would be developed to provide an additional annual yield at Essex of 130,000 acre-feet.

As shown in Table 8 the estimated capital cost of enlarging Ruth Reservoir to provide an additional yield at Essex of 27,000 acre-feet is about 3.8 million dollars. Cost of the project was amortized over a one hundred year period with an interest rate of 3.125 per cent. Annual operations and maintenance cost were assumed to be one-half of one per cent of the capital investment. The resulting annual cost of raw water at the river site, therefore, would be $143,500 or $5.31 per acre-foot. The estimated cost of the Anderson Ford Dam is 24 million dollars. However, when operated in conjunction with Ruth Reservoir the Anderson Ford Dam will not be required until the year 1980. The capital cost was discounted to the year 1970 and expressed as a total annual cost. The annual cost was found to be $830,700 or $6.39 per acre-foot. The annual equivalent cost of water over the hundred year period for both stages of development was found to be $974,200 or $6.20 per acre-foot.

It is possible to develop the entire projected municipal and industrial need of 244,000 acre-feet per year by construction of a reservoir at Butler Valley. If a single-purpose dam with an annual yield of 157,000 acre-feet were constructed at Butler Valley and used to supplement the 85,000 acre-feet presently obtained from Ruth Reservoir and the 2,000 acre-feet per year available from existing individual water systems, it would be possible to meet the projected need for 244,000 acre-feet by the year 2070. The estimated capital cost of such a reservoir is 18 million dollars. Using an annual operation and maintenance cost of one-half of one per cent of the capital cost and amortizing the capital cost over a one hundred year period at 3.125 per cent interest it was found that the annual cost of the Butler Valley Project would be $680,000 or $4.33 per acre-foot.

The Butler Valley Project provides the least cost alternative to evaluate the benefits of municipal and industrial water supply. There are also additional factors that have not been evaluated in monetary terms that favor the Butler Valley Project. The Butler Valley Project offers the advantage of a superior method of diversion. The present system of Ranney collectors will not be adequate for diverting future water supplies. This assumption is based upon the following considerations: 1) the present system is located downstream from Blue Lake which has a projected population of 20,400 people. Thus, Blue Lake will be a source of possible contamination to domestic water diverted from the Mad River; 2) silting of the river bed during periods of flood flow clogs collection beds and

TABLE 8

COST OF ALTERNATIVE PLANS

Alternatives	Additional Annual Yield at Essex	Capital Cost($) (1970)	Capital Cost($) 1970-2070 [a]	Annual O & M ($) [b]	Total Annual Cost($)	Cost Per AF($)
Ruth (First Stage)	27,000 AF	3,800,000 [c]	124,500	19,000	143,500	5.31
Anderson Ford (Second Stage)	130,000 AF	22,000,000 [d]	720,700	110,000	830,700	6.38
TOTAL	157,000 AF	25,800,000	845,200	129,000	974,200	6.20
Butler Valley	157,000 AF	18,000,000 [e]	590,000	90,000	680,000	4.33

a/ 100-year period and 3.125 per cent interest.

b/ Annual 0 & M assumed to be equal to 1/2 of one per cent of the capital investment.

c/ Source: Winzler and Kelly [18].

d/ 1970 capital cost obtained by taking the present worth of $24,000,000 which is the estimated cost of construction of Anderson Ford in the year 1980. Anderson Ford is delayed until demand is required (approximately 1980).

e/ Source: California Department of Water Resources [19] [20].

reduces their capacity; and 3) there is insufficient river bed area suitable for the additional Ranney collectors which will be necessary to divert increased water supply requirements. For these reasons it will be necessary at some time in the future to develop an alternative diversion system. The Butler Valley Dam, which is located much closer to the area of use than Ruth Reservoir, lends itself to the development of direct diversion from the reservoir.

QUALITY DIFFERENCES

Both the Butler Valley and the Ruth Reservoir projects would be used to develop the runoff of the Mad River. The effect of the two reservoirs upon the quality of water released will probably be similar. Elevation, temperature, evaporation and other factors that would affect the quality changes are not significantly different for the two reservoirs. The Butler Valley Project would have the advantage of reduced turbidity since it is possible that in the future, diversions could be made directly from Butler Valley Reservoir. This could provide a water with reduced turbidity if construction and operation of the reservoir were to take advantage of the reduced sediment load resulting from settling in the reservoir. Because of the distance from the place of use to Ruth Reservoir, it is impractical to divert directly from the reservoir. If Ruth is utilized, instream diversion works or the present Ranney collector system must be utilized.

The improved quality of the water due to decreased turbidity would be beneficial because of reduced treatment costs of water used to supply both municipal and industrial requirements. Because of the large number of alternatives that are available for diversion of Mad River water to the area of use, no attempt was made to measure the value of improved water quality that would accrue from these alternate diversion schemes. It should be recognized that diversion directly from Butler Valley Reservoir through multi-level inlets would provide the water of lowest turbidity.

X. OTHER EFFECTS OF PROJECT ON WATER QUALITY

WATER QUALITY IN RESERVOIRS

The California Department of Water Resources has been conducting water quality surveys on Ruth Reservoir. Unpublished records from their office files have shown that stratification is a common phenomenon in this reservoir. Temperature, turbidity, pH and dissolved oxygen stratifications have been observed. In addition phytoplankton studies have shown that algae is prevalent during the summer months although not in bloom proportions. A most significant observation is the presence of blue-green algae in Ruth Reservoir. Turbidity studies in Ruth Reservoir have shown that water is highly turbid immediately after heavy runoffs and this turbidity persists for a long time thereafter. Stratification of highly turbid water in the bottom of the reservoir is common. To avoid the water quality problems induced by stratification, serious consideration should be given to a multiple level outlet structure.

Mineral concentration in the reservoir could cause water quality changes. Manganese and iron deposits in commercial quality are present in the drainage area. Current analyses show the presence of trace amounts which could become a problem by concentrating in the hypolimnion. Hutchinson [21] reported that drainage from coniferous forest may be enriched in manganese. Manganese and iron are oxidized, precipitated and settled to the bottom of the reservoir under aerobic conditions. The precipitates go into solution under the anaerobic conditions of the hypolimnion and would come to the surface during the fall turnover. Manganese and iron are detrimental to domestic use as well as to the pulp and paper industry.

One source of pollution that is difficult to determine is that from forest land drainage. Sylvester [22] reported that drainage from forest land can bear significant levels of nitrogen and phosporus. These nutrients from natural runoff, when added to existing low concentrations, could increase the algal growth potential of impounded water.

Development of the water resources of the basin will be accompanied by significant recreational developments. Fishing, boating, aquatic sports, hiking and camping will increase visitors to the presently isolated area of the upper basin. The Corps of Engineers have estimated that by 2020 about 2,000,000 visitor days per year will be expected in the Butler Valley Reservoir recreational areas. In addition a full capacity of about 500,000 visitor days is expected in the Ruth Reservoir area by 2000. The projected recreational uses could induce potential pollution problems in the upper basin unless proper facilities are provided for these developments. Every effort should be made to contain waste on land to prevent pollution and contamination of both ground and surface waters. Furthermore, entry of

sewage nutrients into the reservoir from sanitary facilities and wastes from pleasure crafts could create water quality problems. The development plans for the recreation areas are very tentative at the moment. However, since extensive recreation usage is planned, a thorough review of proposed sanitary facilities should be made while the project is still under design to insure protection of water quality in the reservoir proper and watershed draining thereto.

EFFECTS OF PROJECT CONSTRUCTION

During the construction of the project, adequate measures must be taken to protect both surface and ground waters. Provisions should be included in contract specifications so contractors would be cognizant of requirements to protect water quality in the work area. Silt detention basins should be constructed at all work areas to eliminate excessive turbidity leaching from earth work. In equipment maintenance areas, special precautions should be taken to contain spilled fuel, lubrication products and wash water. Sewage from construction camps should be contained on land. All construction activities affecting water quality should comply with requirements of local and state water quality control authorities. Comments from the Federal Water Pollution Control Administration should be requested by the construction agency during the preparation of project plans and specifications in compliance with Executive Order 11288.

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APPENDIX

APPENDIX

WATER USE PROJECTIONS

The prediction model for water supply requirements in the Mad River - Eureka area which is presented herein is based upon the following five categories of use:

1. Heavy Industry (pulp)
2. Light Industry
3. Service Industry
4. Domestic
5. Tourist and Recreation

Heavy industry is defined as those industries that are heavy water users. The pulp mills on Samoa Peninsula are considered the only heavy water users in the area. Light industries utilize a much smaller quantity of water. Saw mills, dairies, and food processors are included in this category. Service industries include restaurants, cleaners, and service stations. Domestic use includes all of the water used in the home. Tourist and recreation use includes water used for sanitary and service needs.

Present per capita water requirements for each category and probable changes in demand for domestic heavy industrial use were used to estimate future per capita water requirements. Variation in per capita demand was estimated by means of comparison with projected national, state, and local requirements. It was assumed in making these projections that quantity would not be a constraint on future use. The per capita water requirements used to project future water supply needs are shown below.

Heavy Industrial (Pulp)	=	60,000 gallon/ton pulp
Light Industry		100 gallons per capita day
Service Industry		20 gallons per capita day
Domestic		100-190 gallons per capita day
Tourist and recreation		20 gallons per capita day

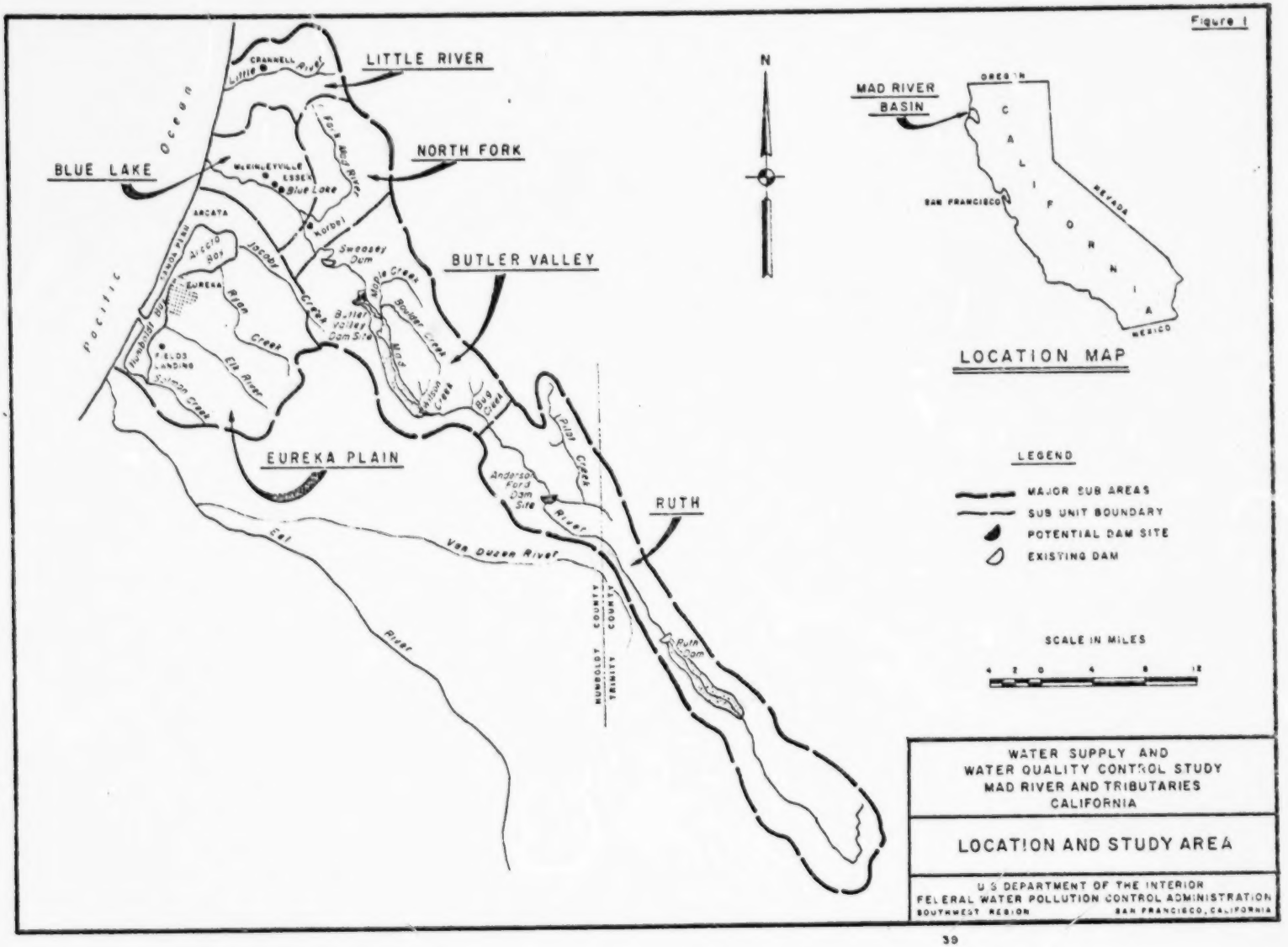
Population and employment projections to the year 2070 were supplied by the Corps of Engineers. These projections are shown in Tables 4 and 5. These population and employment projections and the per capita water requirements were utilized to compute the water supply requirements. Table 9 outlines the projected water supply requirements for the study area.

TABLE 9

COMPUTATION TOTAL
WATER SUPPLY REQUIREMENT
(Gallons per day)

AREAS	1965	1970	1980	1990	2000	2010	2020	2030	2050	2070
Little River,										
Domestic	381,400	495,000	636,000	806,000	1,008,000	1,245,000	1,520,000	1,785,000	2,196,000	2,565,000
Lt. Industry	61,400	69,000	76,000	85,000	100,000	114,000	130,000	140,000	160,000	180,000
Service	13,520	15,600	18,200	21,400	23,400	28,400	31,200	35,200	41,200	45,200
Blue Lake,										
Domestic	445,200	605,000	696,000	837,200	1,064,000	1,380,000	1,760,000	2,244,000	3,060,000	3,876,000
Lt. Industry	70,600	80,000	82,000	85,000	98,000	116,000	134,000	156,000	192,000	217,000
Service	15,220	19,200	20,800	23,400	26,600	31,800	39,000	46,200	60,400	75,400
North Fork,										
Domestic	239,800	286,000	324,000	390,000	462,000	555,000	656,000	782,000	972,000	1,197,000
Lt. Industry	39,400	41,000	42,000	43,000	44,000	45,000	46,000	46,500	47,000	48,000
Service	8,600	8,900	8,700	10,300	11,100	13,900	16,700	20,600	22,500	28,300
Eureka Plain,										
Heavy Industry	25,000,000	60,000,000	120,000,000	120,000,000	120,000,000	120,000,000	120,000,000	120,000,000	120,000,000	120,000,000
Domestic	5,720,000	8,521,700	12,000,000	16,510,000	22,820,000	30,750,000	40,640,000	52,700,000	70,920,000	81,700,000
Lt. Industry	892,300	1,025,000	1,183,000	1,374,000	1,685,000	2,073,000	2,480,000	2,970,000	3,650,000	3,870,000
Service	251,440	354,500	458,600	569,800	706,200	885,200	1,104,000	1,326,000	1,690,000	1,806,000
Butler Valley,										
Domestic	235,600	286,000	348,000	426,000	490,000	585,000	704,000	867,000	1,152,000	1,463,000
Lt Industry	38,000	40,000	43,000	45,000	46,000	46,000	46,500	48,000	50,000	50,000
Service	8,380	9,500	9,700	10,100	11,700	13,700	17,400	21,000	28,600	36,600
Ruth,										
Domestic	28,900	33,000	42,000	52,000	61,600	69,000	80,000	88,400	100,800	114,000
Lt. Industry	5,700	6,000	6,000	6,000	6,400	6,500	6,500	6,500	6,500	6,500
Service	820	900	1,100	1,300	1,400	1,400	1,600	1,600	1,600	1,600
TOURIST AND RECREATION	32,700	5[illegible],500	87,000	131,000	163,000	190,000	190,000	190,000	190,000	190,000
TOTAL gallons/day	33,494,980	71,9[illegible],800	136,082,100	141,426,500	148,828,500	158,148,900	169,602,900	183,474,000	204,540,600	217,469,600
TOTAL AF/YR	37,500	[illegible]1,000	154,000	158,000	167,000	177,000	190,000	205,000	229,000	244,000

Figure 1



WATER SUPPLY AND
WATER QUALITY CONTROL STUDY
MAD RIVER AND TRIBUTARIES
CALIFORNIA

LOCATION AND STUDY AREA

U S DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHWEST REGION SAN FRANCISCO, CALIFORNIA